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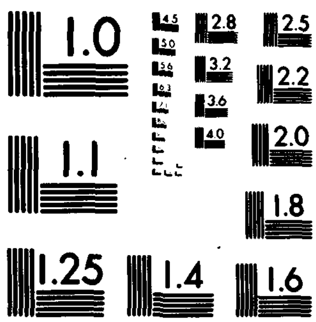

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This contract was the continuation of a previous one for the general purpose of understanding the use of satellite altimetry in physical oceanography. There have been several activities, some of which are continuing. We have published a paper demonstrating a general formalism for using altimetry for the joint purpose of determining the general circulation of the oceans and improving the geoid. Using conventional hydrography in the North Atlantic

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Block 20: ABSTRACT

ocean, a sea surface relative to the geoid has been constructed and will soon be published. The general problem of constructing marine geoids independent of altimetric measurements has been solved in the context of inverse theory. Such geoids are required for subtraction from an altimetric surface to find the ocean current signal. Finally, the principal investigator has been involved in the active planning for a proposed new altimetric mission called TOPEX.

Final rept. 1 Jan - 31 Dec 80

FINAL REPORT - Contract N00014-80-C-0293- Project XXXVI

Determination of the General Circulation of the Ocean and the Marine Geoid Using Satellite Altimetry.

Carl Wunsch
Dept. of Earth and Planetary Sciences
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

1 Dec 80

Our overall understanding of the problems of using satellite altimetry, specifically as determined from SEASAT, and applied to the large-scale general circulation of the ocean is summarized in a lengthy paper by C. Wunsch and E.M. Gaposchkin (1980) which will appear in Reviews of Geophysics and Space Physics (abstract attached). In that paper we attempt to do two things. The first was to describe, at least in qualitative terms, the error fields with which one must deal. These include the tides, wave-height, atmospheric load, ionspheric correction, and atmospheric water vapor. Second, we attempt to show how to use altimetric data sets in the context of existing knowledge of both the ocean circulation and of the marine geoid. A number of simple examples extracted from the SEASAT data were used as illustrations.

A general conclusion we drew from previous work was that to make best use of altimetric data one needed a good starting model of the large-scale ocean circulation in order to treat the altimetrically-determined ocean surface as a perturbation. Using existing hydrographic data in the North Atlantic along with inverse methods, Wunsch and Grant (1980) have computed large-scale circulation models for that ocean. These models are geostrophic and water mass-conserving. From any one of them one can determine the absolute slope of the sea surface relative to the geoid from their computed surface velocities. Such a surface, available also as a spline-interpolated field, has been computed by Wunsch (1980) (abstract attached). The total transport circulation and the resulting sea surface are shown in figures 1 and 2.

Although altimetric satellites can be used to study fluctuations in the large-scale circulation of the ocean without very precise geoids, they are a much more potent tool if total, that is the time-independent plus the time-varying components, of the surface velocity can be computed. For example, to do dynamical calculations, one normally needs to fund the total velocity field, not simply the time-variable protion. But such computations require accurate geoids on as small a spatial resolution as one can get. At present the only known way to obtain geoids at wave lengths smaller than several hundred kilometers is through the use of ship-

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borne gravity surveys. Wunsch and Gaposchkin (1980) showed that the regional geoid in the western North Atlantic computed by Marsh and Chang (1977) has a high degree of accuracy. But they also showed that the difference between the Marsh and Chang geoid and that computed by Mader (1979), ostensibly from the same data with similar techniques, yields differences in the computed geoid which translate into unacceptably large apparent oceanographic signals. The published information does not permit one to deduce which, if either, of these calculations is more correct. More generally, one needs geoids which provide explicit information on both their systematic and random errors as a function of wave-length and position. We have determined that the optimum tool for doing this is once again a form of inverse theory. A paper by Zlotnicki, Parsons, and Wunsch (1980) describes the procedure both in a one-dimensional example and on the required two-dimensional spherical surface.

Wunsch, as chairman of the Science Working Group for the Topographic Experiment (TOPEX), has helped produce a study of an optimum future altimetric mission. To give some of the flavor of that work, we show as figure 3, a highly schematic estimate of the frequency wave number spectrum of the large-scale ocean transport as well as a sketch of the positions in this domain of the errors affecting altimetric satellites. Much of the discussion centers around the degree to which the error fields are correctible by one means or another, and the determination of those parts of the ocean circulation, both time-variable and time-independent, which will constrain the unmeasured parts.

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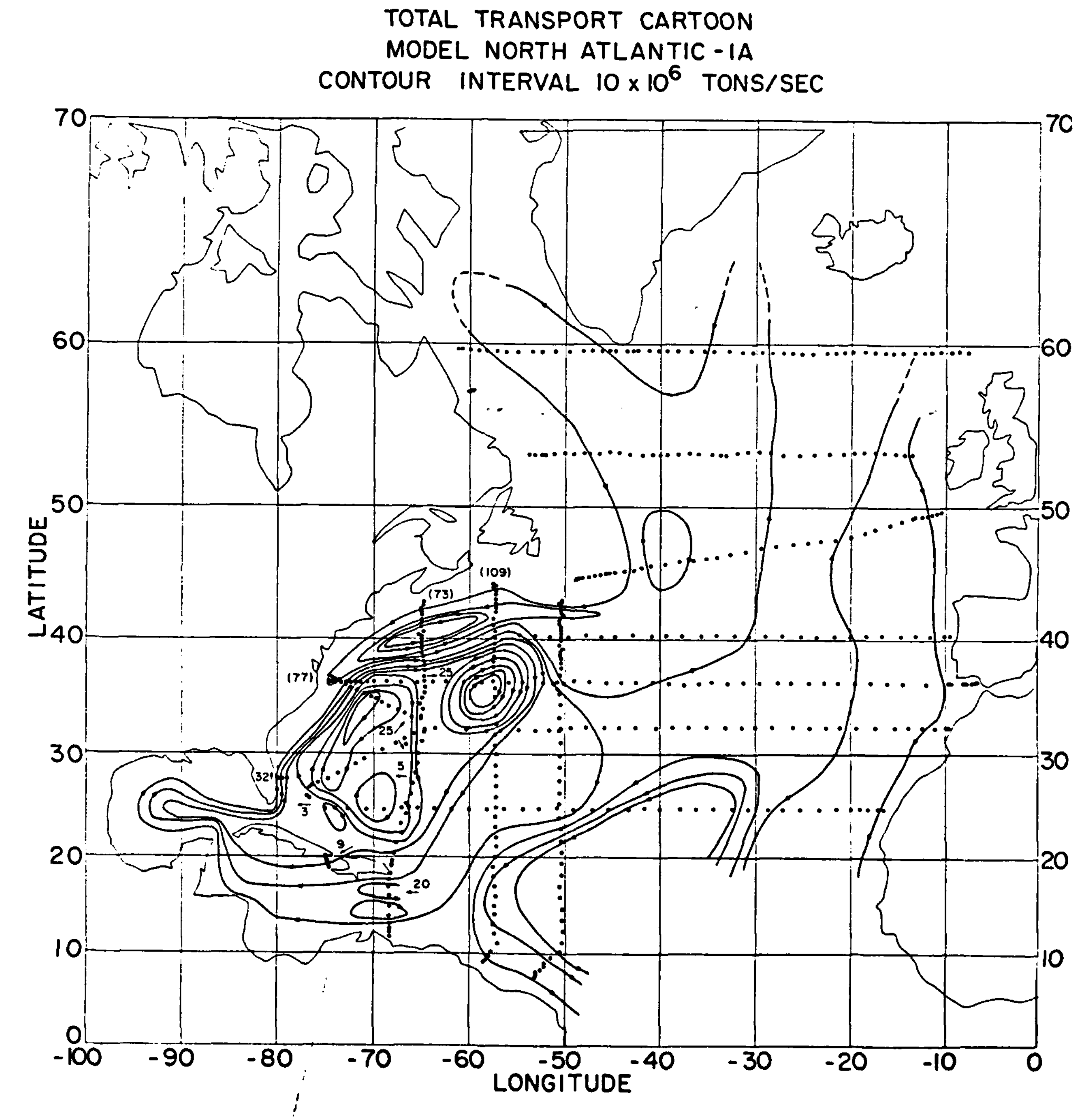
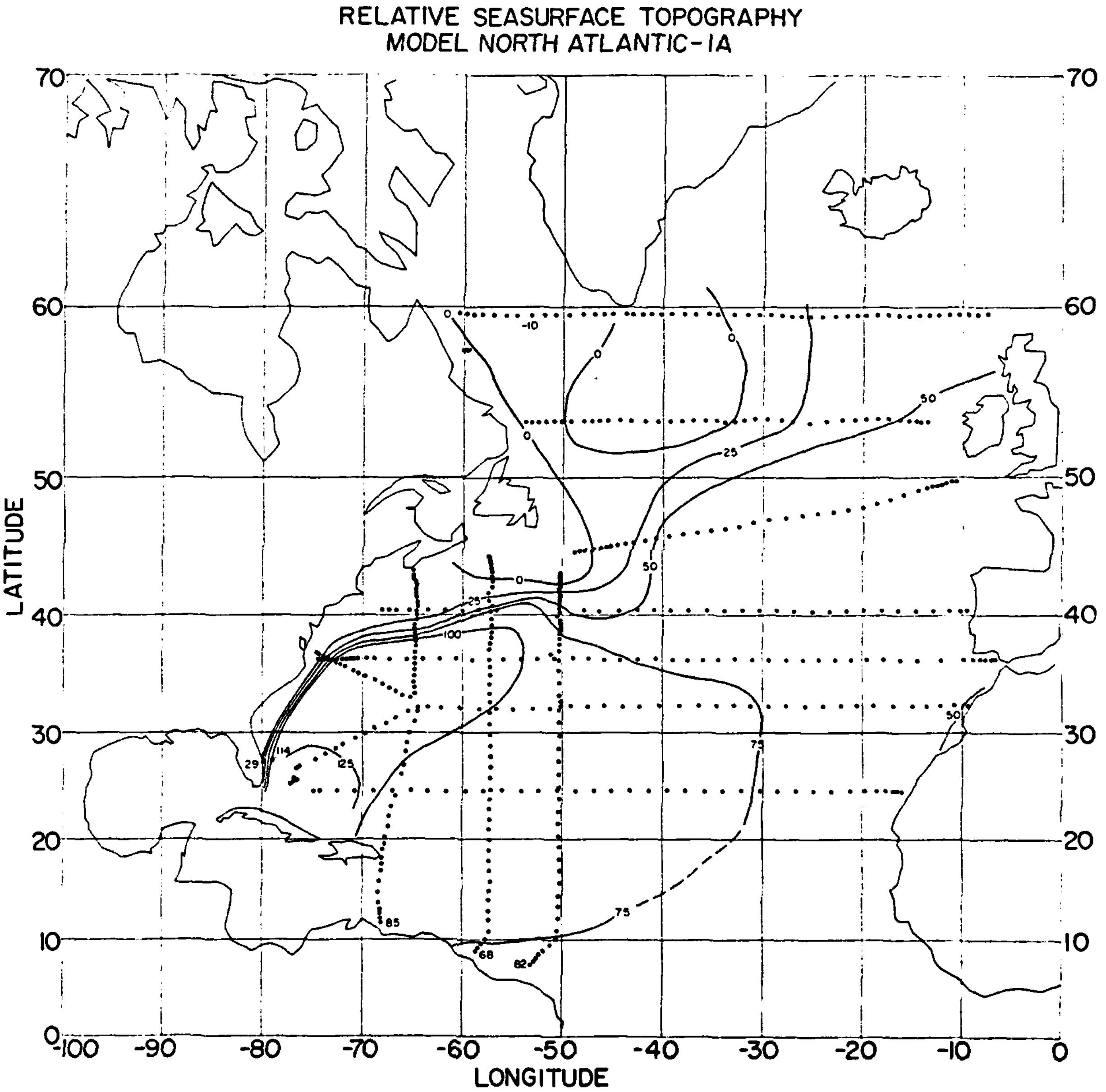
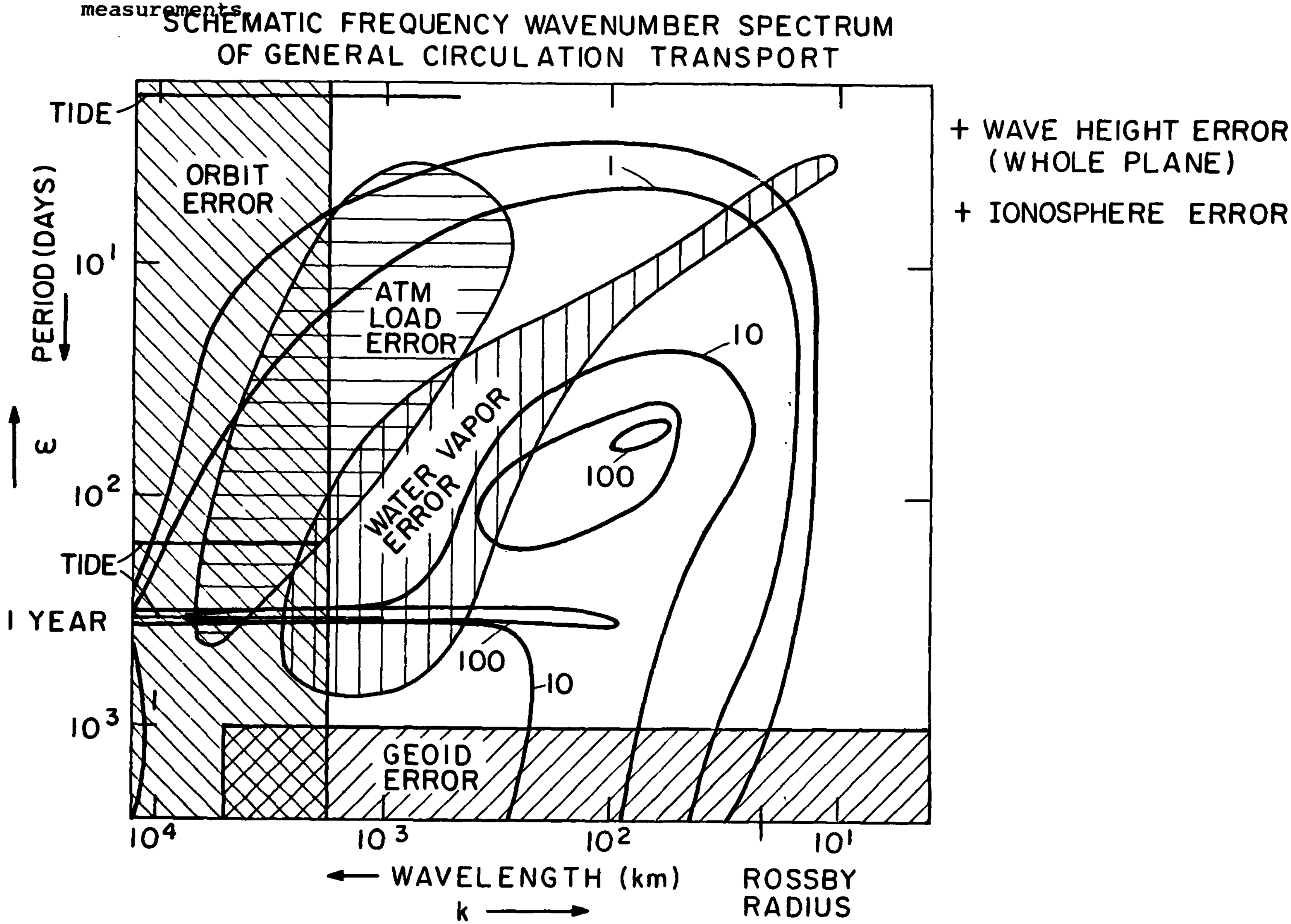


1. Sketch of total (top-to-bottom integrated) transport in an inverse solution for North Atlantic circulation (Wunsch and Grant,1981).



2. Sea surface, relative to geoid, computed from circulation in figure 1 (Wunsch, 1980).

3. Sketch of frequency/wavenumber structure of ocean circulation and a rough estimate of the structure of errors involved in altimetric measurements.



ABSTRACTS

Carl Wunsch - An interim relative sea surface for the North Atlantic Ocean.

An estimate has been constructed of the sea surface, relative to the geoid, in the North Atlantic. The basis of the estimate is the surface geostrophic velocity determined from an inverse solution for the general circulation. The result is broadly consistent with previous surfaces based upon reference levels and with estimates of the longshore, deep-sea pressure gradients inferred from continental shelf measurements.

Carl Wunsch and E.M. Gaposchkin - On using satellite altimetry to determine the general circulation of the oceans with application to geoid improvement.

We describe the problem of combining hydrography with marine geodesy and satellite altimetry for the purpose of determining the general circulation of the oceans, defining the eddy field and improving the marine geoid. The critical problem is to understand the error budgets of four fields: orbit, height measurement, geoid and ocean water density. Corrections must be made for atmospheric load, tides, tropospheric water vapor, wave height and other parameters. A general formalism for deducing the geoid and ocean circulation is obtained in terms of inverse theory and applied to some limited examples.